DUPLICATE

Forecasting Research

Forecasting Research Division
Technical Report No. 123

A Review of the Autosat-2 Project

METEOROLOGICAL OFFICE.

Forecasting Research Division Technical Report No.123

A review of the Autosat-2 project.

Bracknell::::1994:Pp.16:30cm:

94110689 551.501.86
06(b)
681.3.02

by

Richard Allam

October 1994

ORGS UKMO F

National Meteorological Library
FitzRoy Road, Exeter, Devon. EX1 3PB

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

A review of the Autosat-2 project

R.J. Allam,
Forecasting Research Division

7th October 1994

Prepared for a lecture given to the MSc course in Astronautics at Cranfield University, 6th May 1994

1 Abstract

This paper reviews the history of the project that resulted in the implementation of Autosat-2, the Met. Office's operational computer system for generating meteorological products from satellite imagery data. Significant events that influenced the progress of the project between its inception in 1983 and its conclusion in 1992 are noted. At certain points where key decisions were made, the situation is summarized and the decision justified.

A summary of the achievements of the system is presented and compared with the equivalent expectations as conceived at the start of the project. Some conclusions that can be drawn from the experience are noted.

2 Introduction

Autosat-2 is the Met. Office's operational computer system that generates various products from a number of satellite data streams. This paper attempts to review the history of the project to introduce the system, and follows events from the inception of the project in 1983 to the operational status of the system in 1992. It is hoped that an analysis of the events that occurred and the decisions made in response to them may be used to guide those involved in future major projects.

The information presented in this paper was extracted from numerous files containing correspondence and reports made and accumulated during the project. The use of unsubstantiated data, anecdote and memory have been avoided in an attempt to keep the review as objective as possible. Nevertheless, it is inevitable that the incomplete availability of information and the subjective process of selection from those data may have resulted in some distortions or errors in emphasis. The author hopes that any such lapses will not negate the lessons that can be learned from the experience.

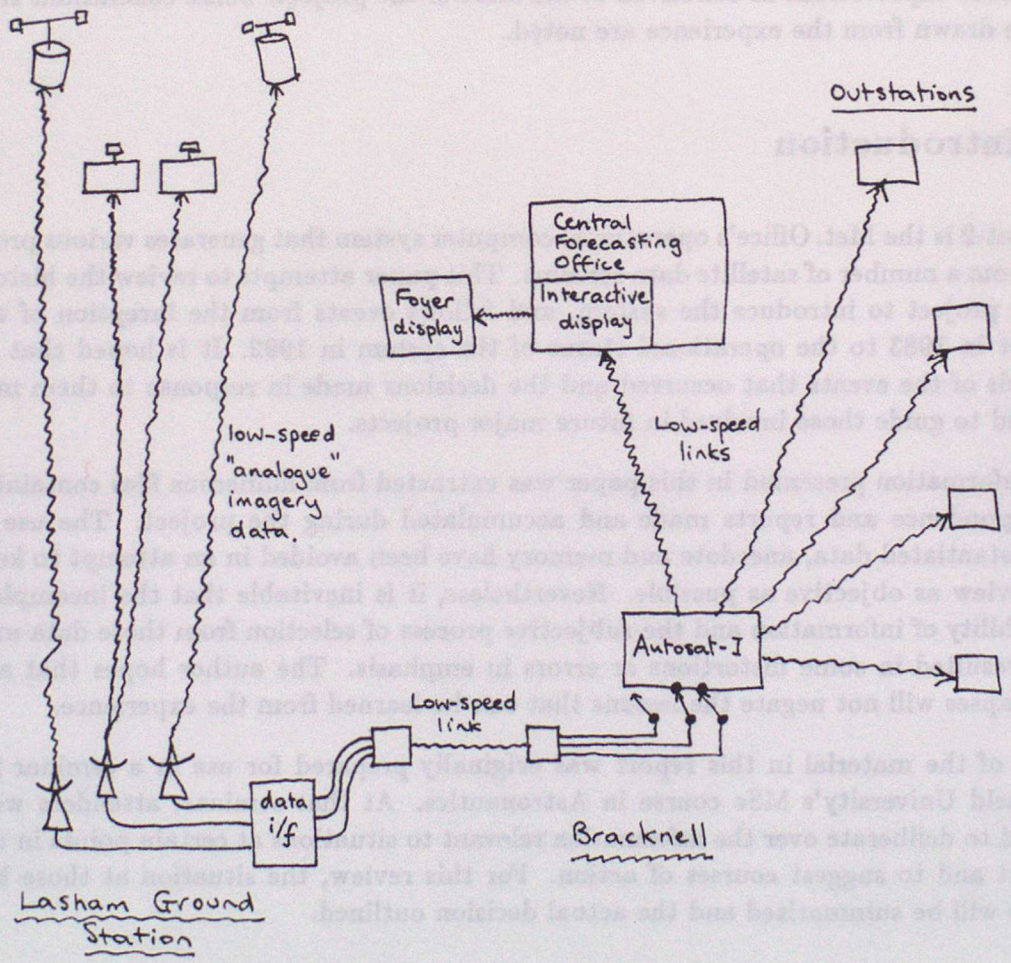
Much of the material in this report was originally prepared for use in a seminar for Cranfield University's MSc course in Astronautics. At that seminar, attendees were invited to deliberate over the information relevant to situations at certain points in the project and to suggest courses of action. For this review, the situation at those key points will be summarized and the actual decision outlined.

3 History of events

3.1 The launch of the idea

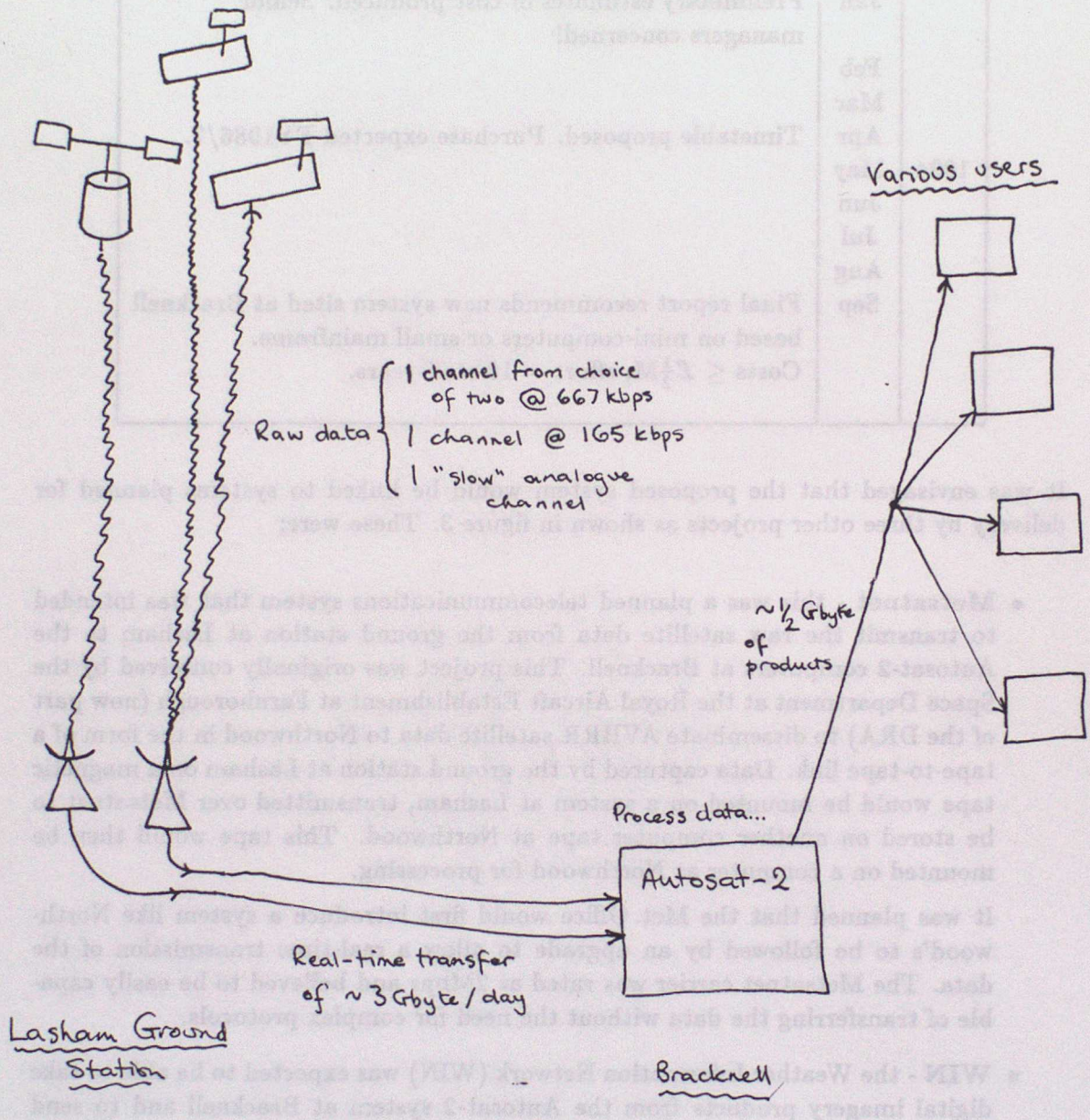
In July 1983, the Steering Group on Satellite Meteorology (consisting mainly of Directors) met to discuss the future of the use of satellite imagery in the Office. They knew that the Office was spending about £5M each year on weather satellite programmes, almost totally with the European Space Agency, ESA. This amount was expected to double within 15 years to pay for the development of the next generation of orbiting platforms. It was also noted that this large investment did not result in a significant contribution to the effectiveness of operational forecasters, who were still reliant on poor quality facsimile output. The cost of running these systems was judged to be very high, particularly when the projected maintenance costs of the computer system that provided the facsimile service, Autosat-1, were taken into consideration. Figure 1 shows the configuration at the time. The research side of the Office had shown that digital imagery could be processed effectively on mini-computer systems

Figure 1
Simplified configuration in 1983



The Steering Group formed a small group to study the feasibility of a new system to be based on the use of digital data streams. This group was asked to look at the user requirement, to provide a technical recommendation and to generate an implementation plan. Figure 2 represents the assumptions under which they were working.

Figure 2



1983	Aug	Group starts work collecting requirements, etc.
	Sep	
	Oct	
	Nov	Group decide user requirements are inadequate. They produce a catalogue of products they believe would be likely to be required.
	Dec	
1984	Jan	Preliminary estimates of cost produced. Senior managers concerned!
	Feb	
	Mar	
	Apr	Timetable proposed. Purchase expected FY1986/7.
	May	
	Jun	
	Jul	
	Aug	
	Sep	Final report recommends new system sited at Bracknell based on mini-computers or small mainframe. Costs $\leq$ £$\frac{1}{2}$M, effort $\sim$ 10 staff-years.

It was envisaged that the proposed system would be linked to systems planned for delivery by three other projects as shown in figure 3. These were;

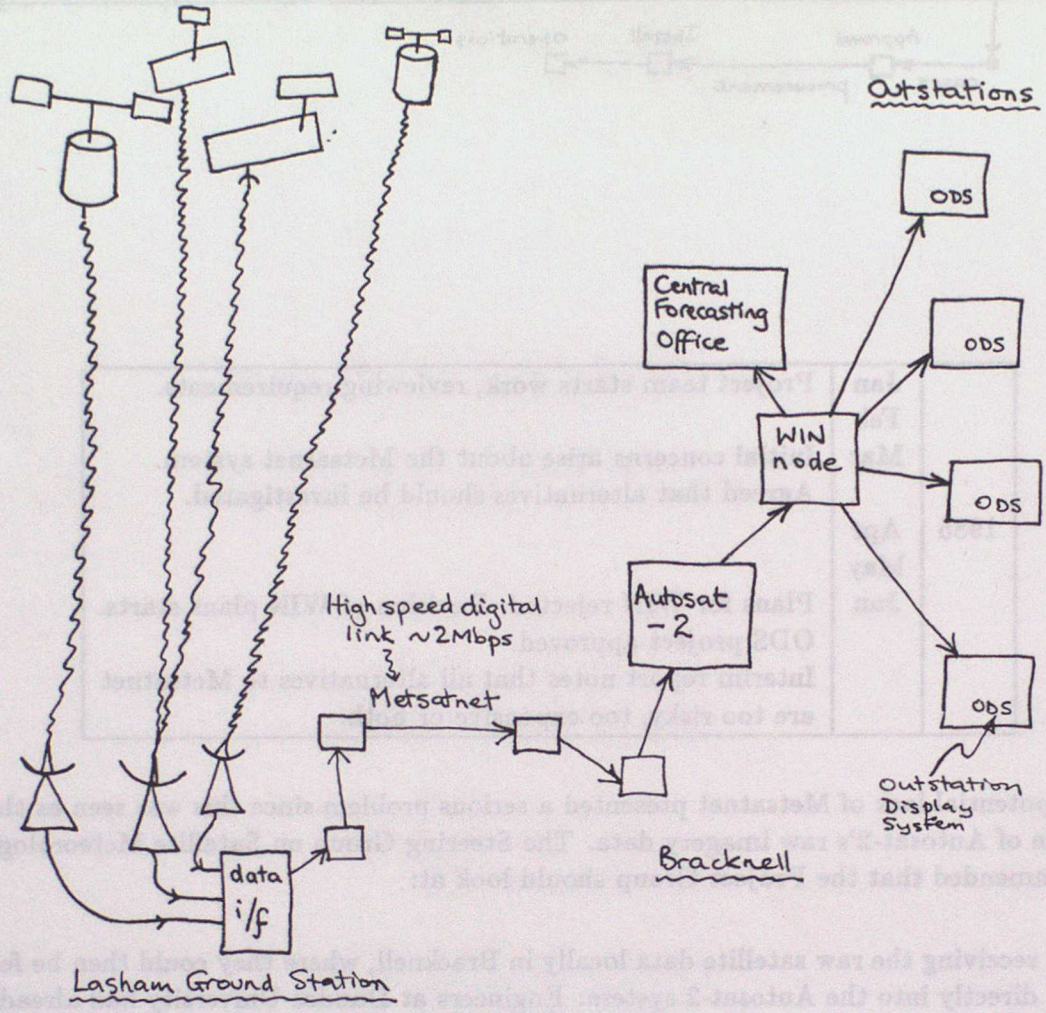
- **Metsatnet** - this was a planned telecommunications system that was intended to transmit the raw satellite data from the ground station at Lasham to the Autosat-2 computers at Bracknell. This project was originally conceived by the Space Department at the Royal Aircaft Establishment at Farnborough (now part of the DRA) to disseminate AVHRR satellite data to Northwood in the form of a tape-to-tape link. Data captured by the ground station at Lasham on a magnetic tape would be mounted on a system at Lasham, transmitted over Metsatnet to be stored on another computer tape at Northwood. This tape would then be mounted on a computer at Northwood for processing.

  It was planned that the Met. Office would first introduce a system like Northwood's to be followed by an upgrade to allow a real-time transmission of the data. The Metsatnet carrier was rated at 2Mbps and believed to be easily capable of transferring the data without the need for complex protocols.

- **WIN** - the Weather Information Network (WIN) was expected to be able to take digital imagery products from the Autosat-2 system at Bracknell and to send them to users at the outstations.

- **ODS** - the Outstation Display System (ODS) was expected to be able to display the digital imagery products at the outstations. The replacement of the hardcopy facsimile systems by ODS at the outstations was expected to yield great financial savings and to provide a much higher quality product.

Figure 3
Planned links to and from Autosat-2 in 1984

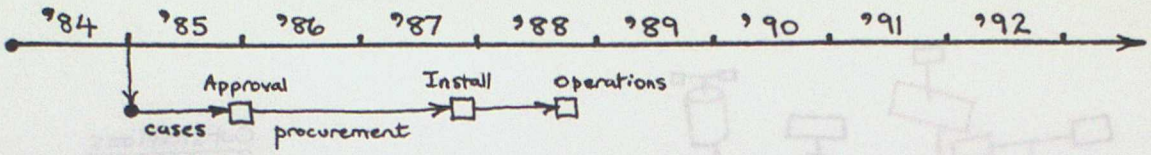


The Study Group on Satellite Meteorology accepted this recommendation and set up an implementation group with the following terms of reference:

- to produce detailed technical and financial cases (as required by internal procurement policy and by MoD);
- to procure the system hardware;
- to implement the system.

The timescales that they specified are shown in figure 4. The implementation group comprised members of the branches responsible for satellite meteorology, systems development, telecommunications and central computing.

Figure 4
Timescales at end of 1984



1985	Jan	Project team starts work, reviewing requirements.
	Feb	
	Mar	Initial concerns arise about the Metsatnet system. Agreed that alternatives should be investigated.
	Apr	
	May	
	Jun	Plans for WIN rejected. Revision of WIN plans starts. ODS project approved. Interim report notes that all alternatives to Metsatnet are too risky, too expensive or both.

The potential lack of Metsatnet presented a serious problem since this was seen as the source of Autosat-2's raw imagery data. The Steering Group on Satellite Meteorology recommended that the Project Group should look at:

- receiving the raw satellite data locally in Bracknell, where they could then be fed directly into the Autosat-2 system. Engineers at Dundee University had already shown that this was technically feasible for both Meteosat and AVHRR data.
- receiving the data at Lasham and processing them on an Autosat-2 system situated at that site. Products generated by the system could then be sent to the users using slower links using standard protocols.

1985	Jul	Options under study by Project Group
	Aug	
	Sep	
	Oct	
	Nov	Report issued.

The Project Group's report concluded;

- local reception at Bracknell would be too expensive to maintain (extra shift workers were envisaged).
- real-time data link betwen Lasham and Bracknell would be too risky or expensive.
- the Autosat-2 computers should therefore be sited at Lasham.

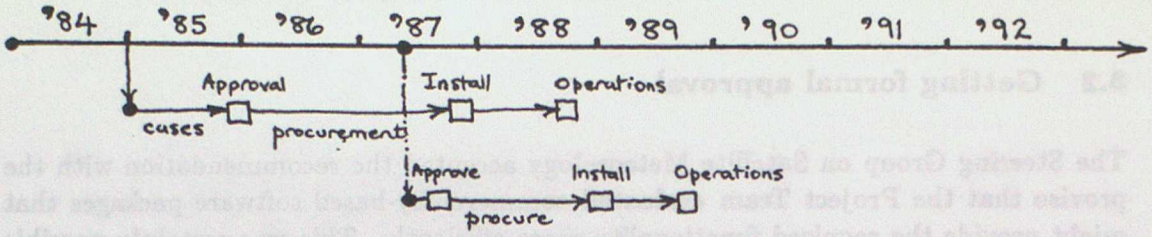
- the largest mainframe computer that could be controlled as part of the Cosmos system in Bracknell (via operating system constraints) was insufficiently powerful. Autosat-2 should, therefore, be based on mini-computer architecture.

3.2 Getting formal approval

The Steering Group on Satellite Meteorology accepted the recommendation with the proviso that the Project Team evaluated commercially-based software packages that might provide the required functionality more efficiently. This was certainly possible since other countries, including Sweden and France, were in the process of developing their own satellite image systems.

1985	Dec	Steering Group considering report
	Jan	
	Feb	
	Mar	
	Apr	Steering Group approve report.
		Project team assess commercial packages.
		All rejected on cost grounds.
1986	May	Central Data Network proposed for communications within Bracknell HQ - based on DECnet.
	Jun	Work continuing on technical case,
	Jul	preliminary design, etc.
	Aug	
	Sep	
	Oct	
	Nov	
	Dec	
	Jan	
	Feb	
	Mar	
	Apr	Technical case approved by Directorate.
1987	May	Central Data Network approved.
	Jun	Internal financial approval granted, case sent to MoD.
		Updated time scales issued (see figure 5).
	Jul	Project Steering Group formed at Branch Director level to manage procurement and implementation phases.

Figure 5
Timescales in mid-1987



At the first meeting of the Project Steering Group, a new scheme was described that would allow the remapping of all satellite imagery to some standard projection. This process would enable the imagery to be combined much more easily with other types of data, including observations and analyses, thereby increasing the effectiveness of the product. Until this time, it had been assumed that the task of remapping would take too long to perform. The user requirement formulated by the group studying the future of Autosat was restricted almost completely to products in the satellite space-view, thereby reflecting not the users' requirements (as we now understand them) but the limitations to the technical capabilities as seen at that time.

It was agreed that yet another attempt should be made to define the user requirement based on the ability to remap images. However, the procurement cycle was now underway; the project could not be slipped significantly while an agreed requirement was established for fear of losing the considerable amounts of money provided for the project in the long-term costings. The procurement continued using intelligent guesses to give the crucial information needed to estimate the characteristics of the computer system.

3.3 The procurement of the system

The process of procuring a fairly large computer system such as Autosat-2 was well understood within the Office. The Systems Development branch provided a timescale that was unlikely to be significantly in error. The process involved making and publishing a detailed specification of the required system - ie the Operational Requirement - which was issued to firms. More detailed discussions were held with interested firms, which resulted in the drawing up of a short-list of those firms. Benchmarks and demonstrations were held to show that the proposed technical solutions were feasible. Detailed Memoranda of Understanding were agreed that listed all of the equipment and services needed to satisfy the Operational Requirement. The firms were invited to tender on the basis of these memoranda and the cheapest compliant tender won the contract. The process was rigid and fair and designed to prevent corrupt practices in the selection of equipment.

	Aug	
	Sep	Operational Requirement issued.
		MoD approve finance for Autosat-2.
1987	Oct	
	Nov	Two key staff resign. 4 month slip in schedule agreed.
	Dec	
	Jan	
	Feb	Three firms short-listed from original seven.
		WIN system is granted technical approval.
		Building work begins at Lasham.
	Mar	
	Apr	Benchmarks are run in UK, USA and in France, the
	May	latter remotely controlled from the UK.
1988	Jun	
	Jul	One firm fails to pass all the required tests, and
		hence is eliminated from competition.
		Files transfers between Lasham and Bracknell
		successfully demonstrated.
	Aug	Two tenders received.
	Sep	
	Oct	
	Nov	Contract awarded to ELXSI, system delivered.
	Dec	Finance for WIN rejected.

3.4 Implementation of the working system

The failure of the WIN system to obtain financial approval created a serious problem for Autosat-2, since WIN was relied upon to disseminate imagery products to the outstation display systems. The user requirement had been derived on the basis of the expected capacity of the WIN circuits.

It was agreed that alternative links should be investigated to send products to the outstations prior to the eventual introduction of WIN. These were based on two complementary schemes:

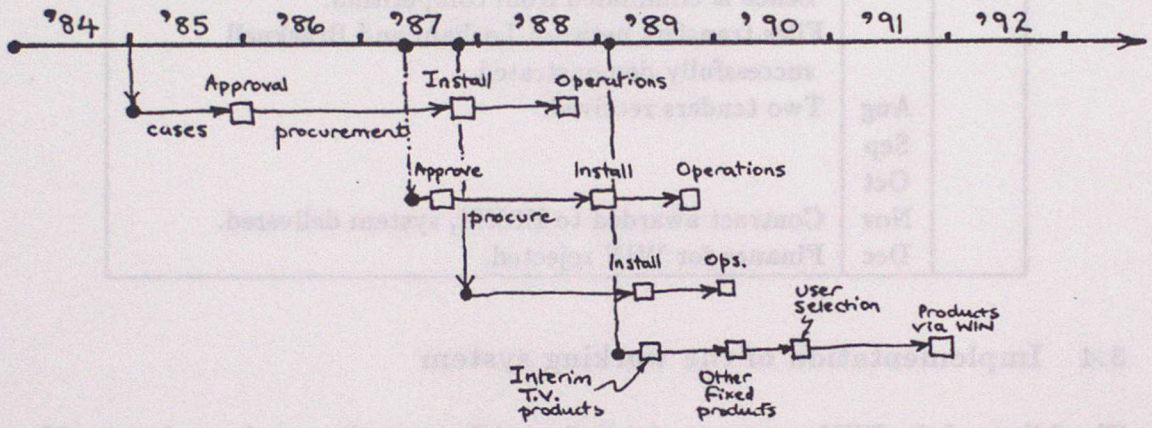
- digital links to the outstations using the MoD's Civil Rented Data Network (CRDN). As far as we are concerned, this is a character-based network which restricted the number of different values that each pixel could have to 64 rather than 256 as had previously been assumed. Imagery products would then be displayed using the ODS.
- a facsimile-based system for sites without the ODS displays. Autosat-1 had been designed specifcally with this type of output in mind, but for Autosat-2, this type of scheme had not been regarded as necessary. A communications system external to Autosat-2 that could drive the existing Satfax machines was sought.

	Jan	
1989	Feb	
	Mar	Media users and project team unable to agree requirements.

Another problem arose in the definition of the user requirement. The media users (ie the groups responsible for providing various television companies with products) were under pressure to supply their clients with imagery showing both standard weather situations and newsworthy global weather disturbances, such as cyclones and hurricanes. They perceived that they would be unable to compete with some companies in the U.S. who had ready access to certain free databases of global imagery.

It was eventually agreed that the project should be re-phased by identifying a series of products to be supplied to various users. With each product was associated a date by which it should be provided. Products for the media users would be provided earlier at the expense of delays in the delivery of products for other users. These timescales are shown in figure 6.

Figure 6
Timescales at start of 1989

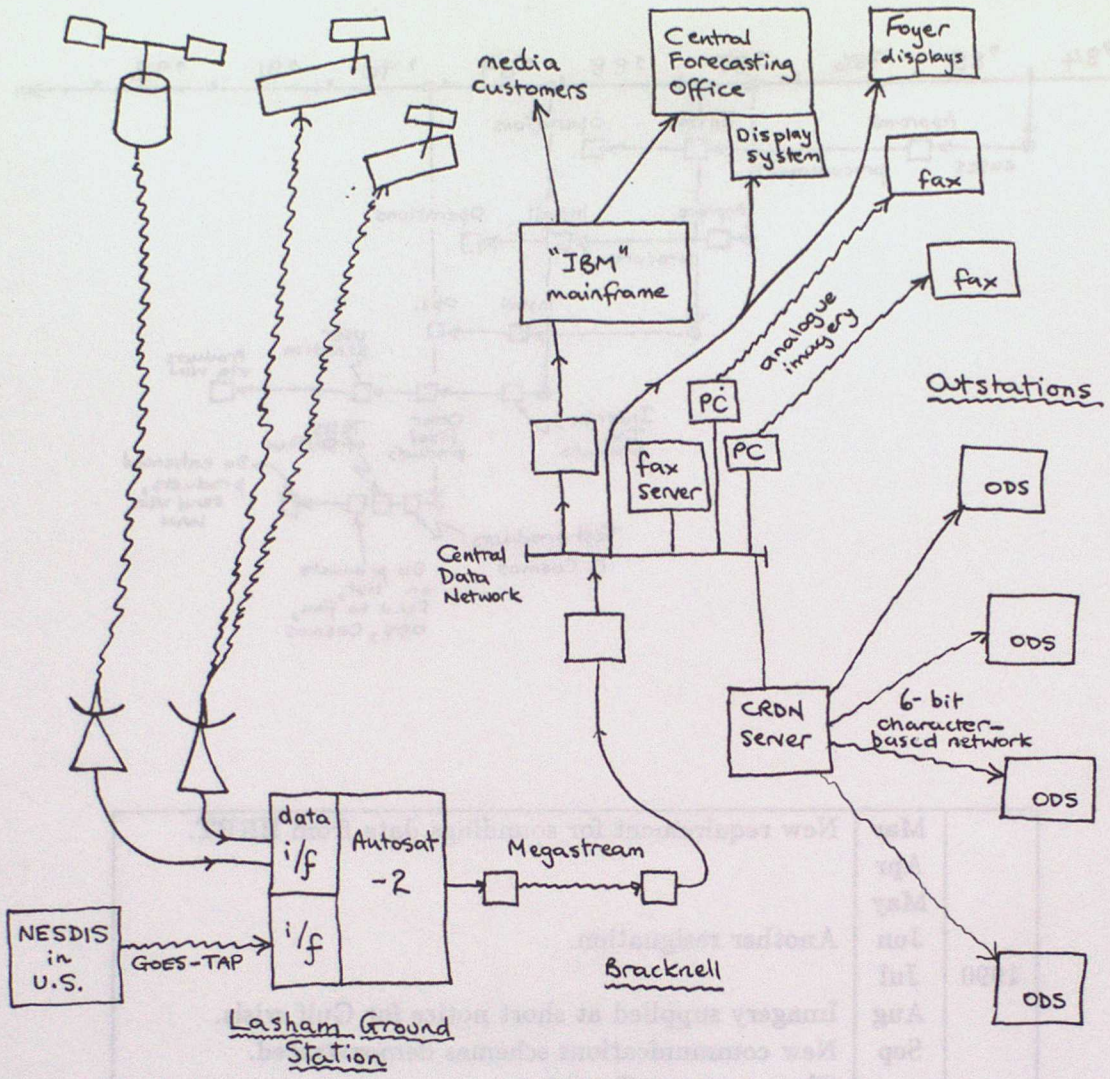


It had originally been intended to provide the global data required by forecasters and later by the media users using imagery supplied from the NOAA-NESDIS data base over the analogue broadcast of NOAA's GOES-east satellite. The demise of this satellite implied that a different source had to be found. This was achieved through the use of a dial-up service into the same NESDIS database, a service known as GOES-TAP. A supply of required products from the GOES and GMS satellites was arranged by the Telecommunications branch. It was envisaged that it would be straightforward to input the analogue data stream into Autosat-2 via a simple interface.

1989	Apr	GOES-TAP agreed as the source of global imagery.
	May	Plans for interim communications systems issued.
	Jun	
	Jul	ELXSI underwent a major restructuring, ceasing hardware manufacture and maintenance.

The two schemes proposed earlier for the supply of data to the outstations were agreed. The resulting structure of the whole system is shown in figure 7.

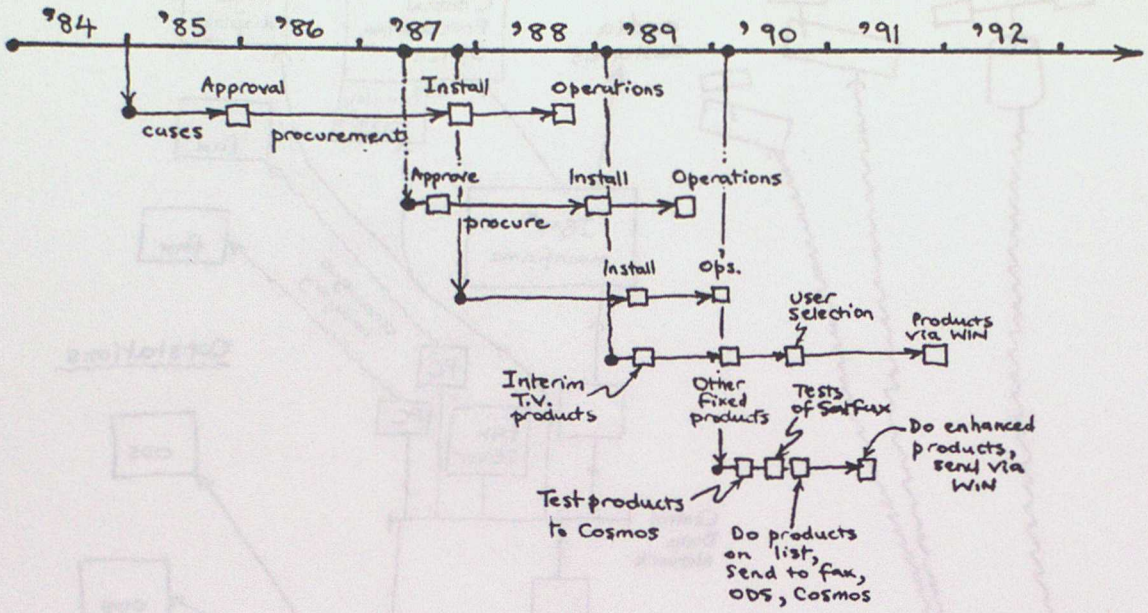
Figure 7 - "Final" configuration



The "major restructuring" of ELXSI caused significant delays in the project as well as uncertainty for the future development of the system. The maintenance of the system was taken over by a services company, who hired some of the engineers from the old ELXSI to train some British engineers. Organising these arrangements took effort away from the design and implementation of operational software. Production of ELXSI hardware continued in Singapore and some software development continued in India. Perhaps the most serious problem was the loss of adequate documentation for the crucial interfaces that ingested the data from the Lasham ground station system into the ELXSI computers themselves.

1989	Aug Sep Oct Nov Dec	Media users receive images for T.V.
1990	Jan Feb	3 more resignations forces slip in schedule. T.V. companies start to use imagery. New schedule issued. See figure 8.

Figure 8
Timescales in early 1990



	Mar	New requirement for soundings data from HRPT.
	Apr	
	May	
	Jun	Another resignation.
1990	Jul	
	Aug	Imagery supplied at short notice for Gulf crisis.
	Sep	New communications schemes demonstrated.
		Three more staff resign.
	Oct	
	Nov	Stream of Meteosat test data to ODS and Cosmos.
		Test products from polar systems to Cosmos.
	Dec	Bug in ELXSI trigonometry routines found - had prevented generation of polar orbiter products.
	Jan	
	Feb	Continuing problems with data inputs. Consequent impact on product reliability, development time, etc.
1991	Mar	Flow of products starts to outstations in digital and facsimile form. Special polar orbiter products generated. All scheduled products supplied but not at required frequency or acceptable delay.
		Workload-dependent system failures detected.

The attempts to supply the users with products were hampered by problems associated with the overload of the ELXSI systems. As more products were generated, the length of time taken for them to be generated also increased to the point where serious delays were taking place. These delays were compounded by those due to the limitations of the product dissemination system (based on CRDN) to transmit the products, and from

competition for the use of the available bandwidth between images and other data. The reliability of the system was also decreasing with the detection of system failures associated with periods of maximum usage. Apparently the system program that manages the mapping of data between virtual and real memory occasionally swapped itself out to disk; there was nothing then running on the system to put it back into memory and the system was locked. In addition, the turn-over in staff resulted in there being insufficient experienced staff to develop the system to the planned deadlines.

A consultant from the old ELXSI company was hired to investigate the problem. He recommended that the system should be radically upgraded. This was agreed, finance for an upgrade having been planned.

	Apr	The System Design team leave project as planned.
	May	
	Jun	
	Jul	Satfax scheme goes operational (ie with backup).
1991		Extra hardware loaned for appraisal purposes.
	Aug	
	Sep	
	Oct	
	Nov	
	Dec	Hardware upgrade approved.
		Working GOES-TAP interface finally available.
	Jan	Plans under development for handover of system to (CF)8 for operational support.
	Feb	Tests of input data from 2nd Meteosat system.
1992	Mar	Hardware upgrade installed, performance radically improves.
	Apr	
	May	
	Jun	Handover plans agreed.
		Stream of products from 2nd Meteosat system.
	Jul	Autosat-2 goes operational.

It is important to note that the problems of interfacing the satellite data streams into the ELXSI computers have never been solved properly. There were problems with the quality of the wiring and with producing the interface to the GOES-TAP data. Also, the inputs from the two geostationary satellites and the GOES-TAP system were not available on each of the two ELXSI computers, preventing the generation of the global imagery products as intended.

The system had gone operational but there remained problems as a legacy of the collapse of ELXSI, including the following:

- there was little scope for expansion of the system due to the likely paucity of spares, especially in the future.
- there was a risk that the maintenance agreement would collapse as other users of ELXSI computers in Europe transferred their applications to other equipment and the viability of maintenance operation decreased.

- the system, being non-standard, would become expensive to support within the Office.

In response, Kirby James (who is the head of the group currently responsible for maintaining the system) wrote a paper recommending that a group be formed to look at the future of Autosat-2. This should include the user requirement, the viability of the existing hardware and the formulation of options for the future. (See decision of the Steering Group on Satellite Meteorology in 1983!).

4 Achievements of Autosat-2

It seems that much of the recent discussion about Autosat-2 has focussed upon its failures. Perhaps it is some sort of compliment that it also gets the blame for the failures of other projects, especially those responsible for the dissemination of products. The following table may help to provide a more balanced picture. It compares the services to be generated by the system as envisaged in 1984 compared with those currently available. Note that the concept of the system in 1984 more or less dictated the complexity of the eventual system through its influence on the user requirement and the financial provision for the system.

Factor	1984	1994	Change
Input channels	4	5	+25%
Output channels	2	7	$\times 3\frac{1}{2}$
Areas covered	7	42	$\times 6$
Product types	4	11	$\times 2\frac{1}{2}$
Categories of customer	7	14	$\times 2$
Daily products			
AVHRR	27	213	$\times 8$
Meteosat	68	438	$\times 6\frac{1}{2}$
Other	6	199	$\times 33$
Total number	101	850	$\times 8\frac{1}{2}$
Total volume /Mbyte	492	541	+10%
Lines of FORTRAN (not comments)	/	80k	/
Effort/staff years	10	35	$\times 3\frac{1}{2}$
Operational service	Summer 1988	Summer 1992	4 years late
Costs (not staff)	£$\frac{1}{2}$M	~£$1\frac{1}{2}$M (estimate!)	$\times 3$

5 Lessons to be learned

Perhaps the following conclusions can be made from the experience of the Autosat-2 project.

- The style of the project changed from a "big bang" (in which all of the products would be delivered operationally at the same time) to a phased delivery of products over a period of time. Perhaps future systems should be planned in this way from the outset.

- There were many difficulties in estimating how long the tasks constituting the project would take. Only some of these were due to external uncertainties. More practice of estimating the resources needed to perform a task within a project framework, together with effective reviews of the outcomes, might be expected to improve the accuracy of estimates.

- There was a shortage of experienced staff throughout the project due to a large throughput of staff, some by planned mechanisms such as promotions, but mostly through resignations. About 40 people worked on the project at some time, but the maximum number of staff working at a particular time was only ten. Between 1987 and 1992, there were only four posts in the Satellite Imagery group with significant responsibilities for Autosat-2, but twelve people occupied them at different times throughout the period. The System Design group was especially affected by the turn-over in staff.

- The generation and agreement of a user requirement was problematical throughout the project and remains so now. Part of the problem was due to the difficulty in managing the complex communications needed between two groups of people who are experts in their own fields but not so in that of the other group. It was not possible for the users to specify accurately a set of imagery products without knowing what could be provided. Neither is it possible for experts in the processing of imagery and design of computer systems to determine what products the users need. It should also be recognised that the perceived requirements for imagery will inevitably change over time. The implementation of systems should try to allow for such changes.

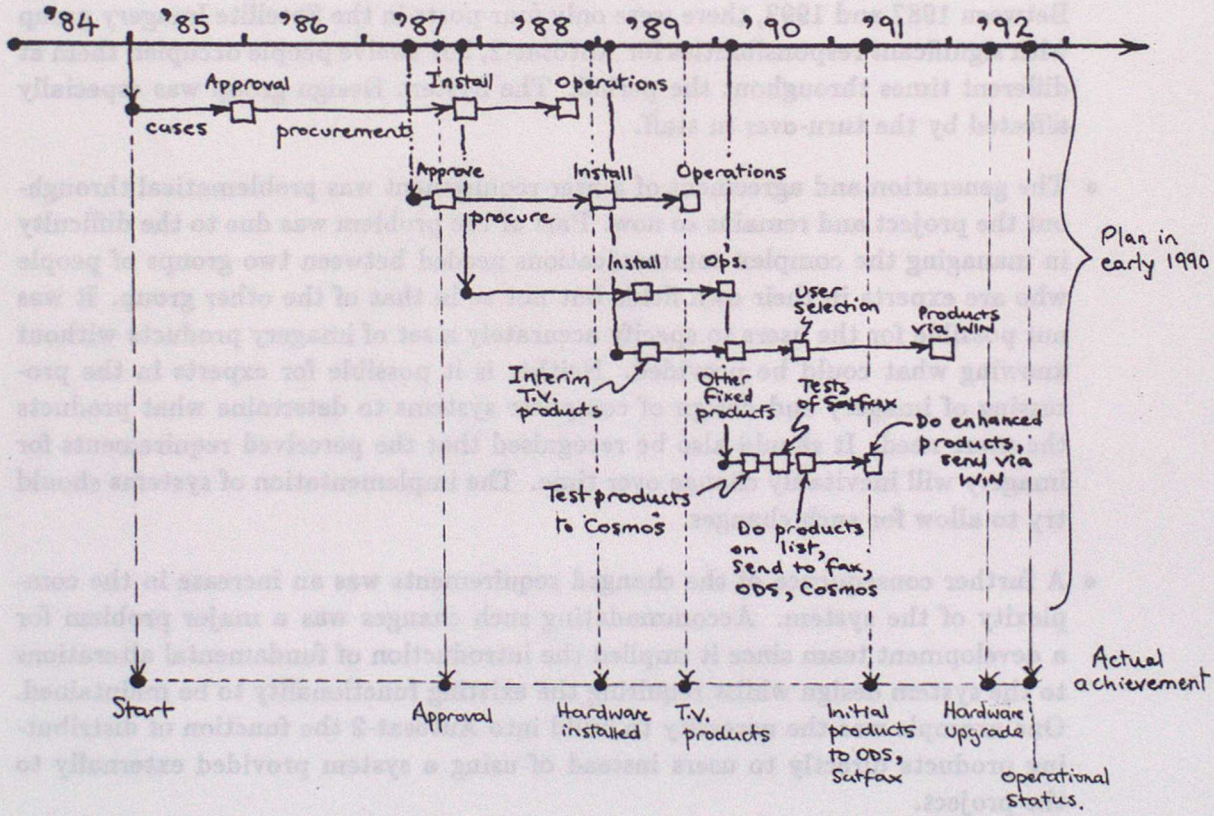
- A further consequence of the changed requirements was an increase in the complexity of the system. Accommodating such changes was a major problem for a development team since it implied the introduction of fundamental alterations to the system design whilst requiring the existing functionality to be maintained. One example was the necessity to build into Autosat-2 the function of distributing products directly to users instead of using a system provided externally to the project.

- The successful implementation of Autosat-2 depended on the success of a number of other key projects over which there was no control. Failures or problems with at least four of these projects caused serious delays through the need to provide alternative solutions or otherwise recover from the resulting situation. These were;
  - Metsatnet;
  - WIN;
  - ELXSI computers - hardware, system software and FORTRAN;
  - the Lasham ground station's data supply system.

  Perhaps it could be argued that the Autosat-2 project was too ambitious or too vunerable to perturbations in its environment, but it is difficult to see how anything could have been done to reduce these particular risks.

A final view of the timescales of the project is shown in figure 9.

Figure 9
Timescales - final achievements



6 Acknowledgements

The author gratefully acknowledges the advice and hard work of the many people who contributed to the project, even to those who left for more lucrative jobs. Special thanks are due to John Ponting of the Systems Development branch, without whose technical expertise, boundless energy and common sense the project would not have achieved what it did.